OFFICE OF RESEARCH & DEVELOPMENT
2012 R&D REVIEW

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Assessment of a Diesel Vapor Reclamation System for Use in Diesel Electric Locomotive

U.S. Department of Transportation
Federal Railroad Administration

Program Area & Risk Matrix

Assessment of a Diesel Vapor Reclamation System for Use in Diesel Electric Locomotive

Program Areas / Risk Factors	Trespass	Grade Crossing	Derailment	Train Collision	All Other Safety Hazards
Railroad Systems Issues					
Human Factors					
Track & Structures					
Track & Train Interaction					
Facilities & Equipment					
Rolling Stock & Components					
Hazardous Materials					
Train Occupant Protection		X	X	X	
Train Control & Communications					
Grade Crossings & Trespass					

Objectives

- **Investigate vapor generation potential in fuel tanks of diesel locomotives due to fuel consumption and fuel heating**

- **Design a vapor reclamation system that:**
  - Removes vapor from tank to reduce the potential fire risk associated with vapor ignition in a breached tank.
  - Condenses vapor back to fuel and returns to the tank for re-use.

- **Develop a system for integration with a locomotive and performance evaluation**
  - Components of vapor reclamation system
  - Temperature, vapor condition monitoring and data acquisition system
  - System integration strategy for specific class of freight locomotives

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Background

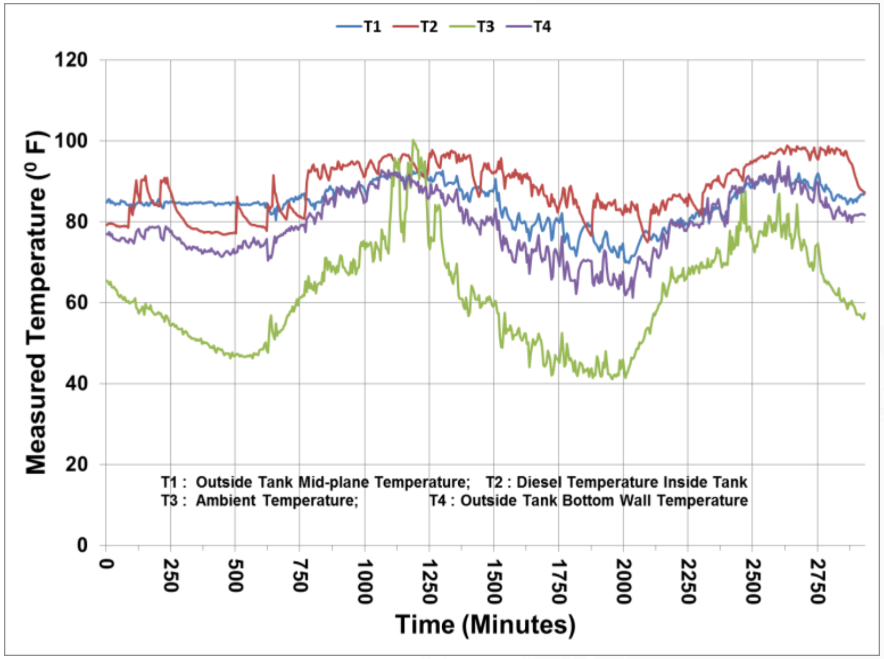
- **Diesel vapor reclamation through condensation of diesel vapor feasibility demonstrated through proof-of-concept laboratory tests**
- **Computational Fluid Dynamics (CFD) prediction for scaled tank -airflow rate adequate for a steady state vapor reclamation in the lab tests**
- **Reclaimed fuel analysis showed:**
  - Similar specific heat and hydrocarbon constituents
  - Fuel reusable in a locomotive
- **Critical missing data:**
  - Fuel temperature of a running locomotive
  - Temperature differential between fuel and ambient

Fuel Temperature Data Collection

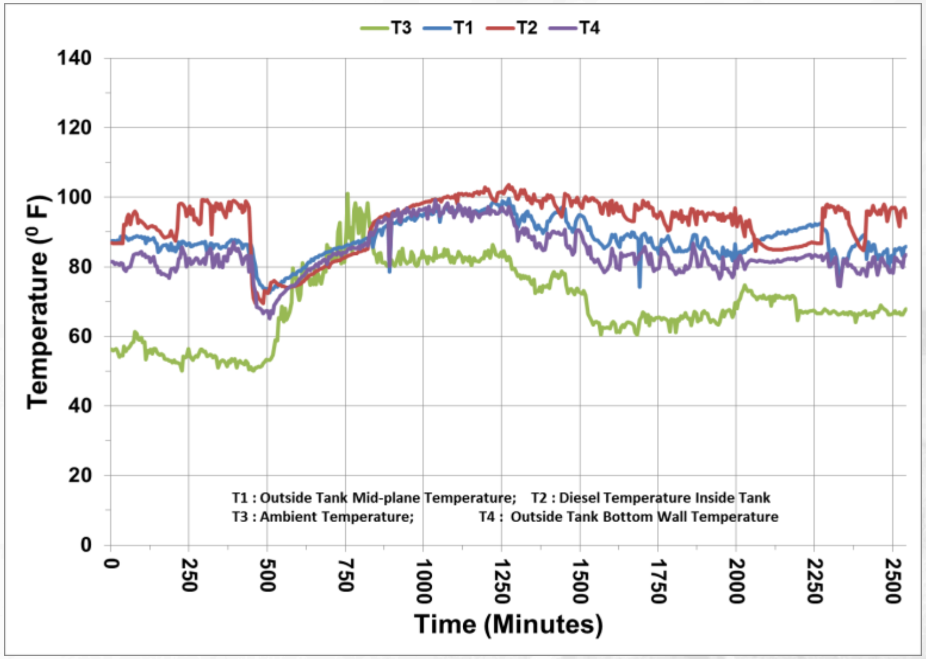
- Four channel digital data logger was used to monitor temperature data
- Data recording interval set at 20 seconds
- One hermetically sealed thermocouple inserted into fuel tank
  - Three thermocouples used to monitor ambient air, tank side wall and bottom wall
- Data collection conducted on a coal training from Kansas City, MO to Birmingham, AL and back to Kansas City, MO (1400 mi / 96 hrs.)

Ambient and Fuel Tank Temperatures

Diurnal variation of ambient temperature and also drop in fuel temp at refueling observed



Temperature data between Kansas City & Birmingham, AL

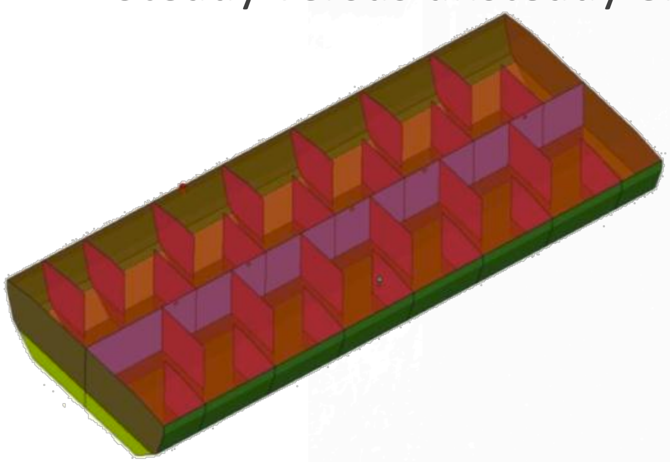


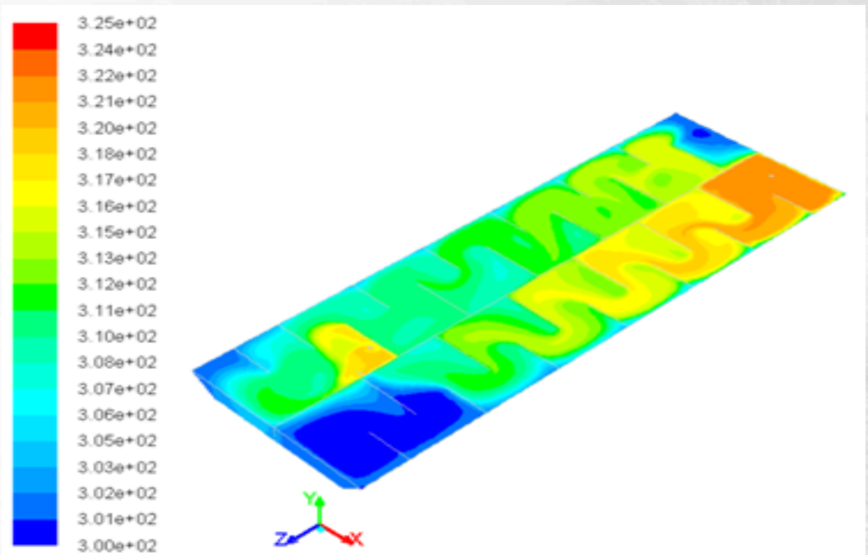
Temperature data between Birmingham, AL & Kansas City

The highest temperature differential between ambient and fuel was 50⁰F

Computation Fluid Dynamics (CFD) Analysis

- CFD analysis (FLUENT) and fuel temperature data used to investigate vapor generation potential in fuel tanks
- CFD computations included coupled physical effects
  - Fluid flow with turbulence
  - Two-phase flow
  - Evaporation from liquid phase into vapor-air mixture
  - Fluid mixture properties change
  - Heat flux due to evaporation
  - Steady versus unsteady effects





Summary of CFD Analysis Results

- Extensive CFD analysis was necessary to understand the complex interactions of several system parameters

- Major factors affecting the diesel vapor mole fraction in tank vapor space are:
  - Fuel temperature – depends on the remaining fuel as well as train speed
  - Ambient temperature
  - Circulating air flow rate in the vapor space

- FAR value inside tank mostly controlled by fuel temperature – other conditions remaining the same

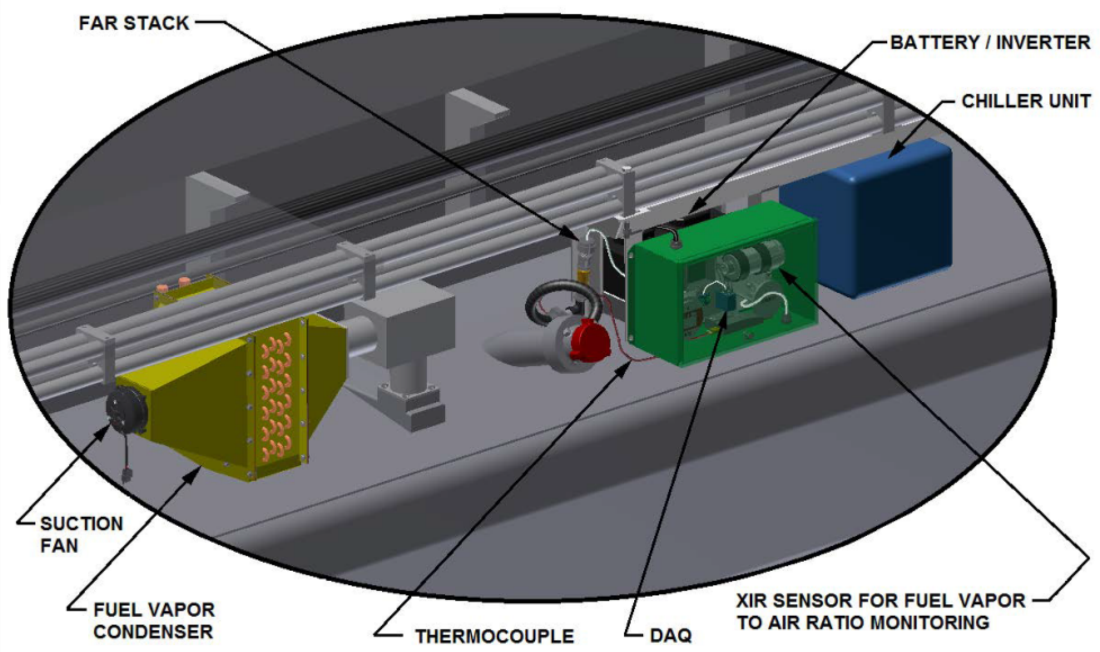
- A drop in ambient temperature from 100^0F to 50^0F causes a drop in FAR at vapor outlet by 58% for 20 cfm and by 61% for 40 cfm airflow

- For a steady 100^0F ambient, airflow rate of 20/40/80 cfm reduces FAR at vapor outlet port by 12% / 18% / 27% respectively

Vapor Reclamation System Design

Essential components of a diesel vapor reclamation system include:

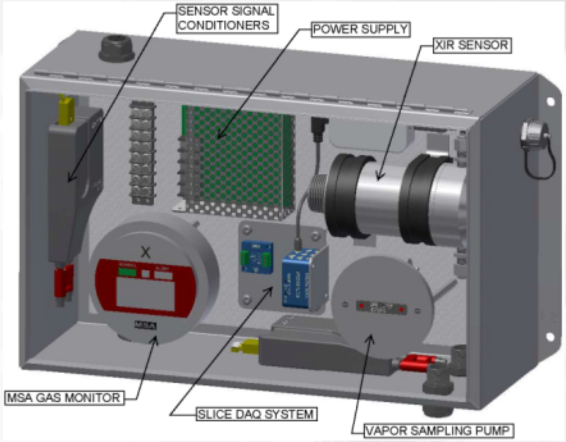
- Air inlet path into fuel tank
- Vapor outlet path from tank – to facilitate vapor extraction by a suction fan
- Diesel vapor condensation unit for converting the vapor to reusable fuel
- Small capacity chiller unit for closed-loop coolant circulation to the condenser
- Data acquisition system for monitoring system parameters

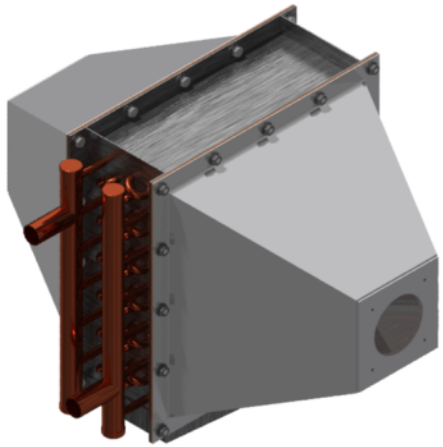


Components of Vapor Reclamation System

Major components include:

- Vapor condenser
- Chiller unit
- Sensors and data acquisition (DAQ) enclosure
- Power supply (Inverter/Battery pack)





Conclusions and Next Steps

- Previous laboratory proof-of-concept tests had demonstrated feasibility of diesel vapor reclamation in a scaled tank
- CFD analysis performed to evaluate the effects of a number of parameters on resulting vapor mole fraction or FAR for a full-scale locomotive tank
- Results of analysis with no forced airflow shows
  - Mixture of vapor and air temperature reaches fuel temperature over time
  - Maximum mole fraction reaches 0.262% - which nearly corresponds to the value at equilibrium vapor pressure for 120 °F – for No. 2 diesel
- To prevent this FAR getting close to the LEL value of 0.3% for certain No. 2 diesel, optimized forced air circulation through vapor space is necessary

Conclusions and Next Steps

Calibration of tank-wall heat transfer coefficient necessary for proper correlation with full scale tank test data

Prevention of hazardous vapor conditions inside tank, minimization of environmental pollution, as well as partial vapor recovery appears possible

Vapor reclamation system component development and integration plan with full-scale locomotive tank completed

Working with BNSF Railway, modifications to the tank fittings will be performed prior to integration of a prototype for system performance evaluation